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Facility Design Criteria AN/GSC-39 (V)1 Earth Terminal Complex Fixed Site Configuration, Addendum I: HEMP Considerations

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RFI/EMI	AN/GSC-39 fixed site	
Cable trench	Transient protection device	
Facility shield	Radio frequency interference	
HEMP hardening	Electromagnetic interference	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This addendum provides high altitude electromagnetic pulse (HEMP) hardening design criteria for the AN/GSC-39 Earth Terminal Complex fixed site facilities. In addition to other criteria, this addendum is to be used for preparing construction plans and specifications for the earth terminal complex. These HEMP criteria are based on two reports for HEMP hardening of the AN/FSC-78 Satellite Communications Terminal. The hardening measures developed in this addendum will enhance protection for the digital communications subsystem.

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FIGURES

1. INTRODUCTION AND SCOPE

This report provides high altitude electromagnetic pulse (HEMP) hardening design criteria for the AN/GSC-39 Earth Terminal Complex fixed site facilities. In addition to other criteria, this report is to be used for preparing construction plans and specifications for the earth terminal complex.

These HEMP criteria are based upon the final reports for HEMP hardening of the AN/FSC-78 Satellite Communications Terminal by the Harry Diamond Laboratories (HDL)[1] and TRW.[2] In addition, these criteria are based upon applicable HEMP design practices established by HDL for the AN/FSC-78 facility at Landstuhl, Germany,[3] and generic HEMP protection designs for the Real Time Adaptive Control System (RTACS) facilities.

Only the facility HEMP hardening requirements for an AN/GSC-39 are described. Separate HEMP protective designs must be applied to the interconnect communications facility (ICF) and the technical control facility (TCF). While not specifically addressing the digital communications subsystem (DCSS), the hardening measures developed in this report will enhance protection for the DCSS.

2. DESIGN CRITERIA—SITE WORK

2.1 Cable Trench

The cable trench is designed to carry the waveguide runs, signal cables, and technical ground run to the antenna for the AN/GSC-39 in a manner similar to that for the AN/FSC-78 shown in figure 1. For hardening the trench to HEMP, an entry plate will be placed at each end of the trench (communications building and antenna pedestal base) to which all waveguides and cable shields will be circumferentially bonded. In addition, the entry plate should be attached to the reinforcement bar (rebar). The rebar in the trench should be connected to the building and pedestal rebars. These designs are to supplement the details of the required trench construction shown in figure 2. Also, these criteria are to be included in the required construction of the trench as an integral part of the antenna support structure.

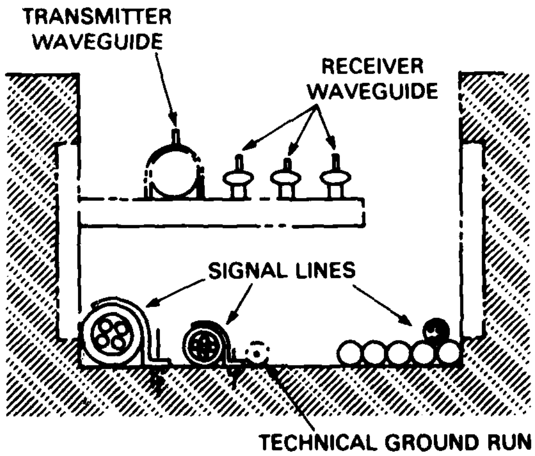

Figure 1. Cross section of cable trench showing waveguides, technical ground run, and signal lines.

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[1] *James D. Penar, Michael Katz, and Ronald J. Chase, HEMP Vulnerability and Hardening Assessment: AN/FSC-78(V) Satellite Communications Terminal, AN/USC-28(V) Spread-Spectrum Modem, and Auxiliary Digital Equipment (U), Harry Diamond Laboratories HDL-TR-1871 (September 1980). (SECRET)*

[2] *E. P. Chivington, W. J. Malloy, P. J. Madle, and T. J. Sheppard, High Altitude Electromagnetic Pulse Hardening Study AN/FSC-78(V) Satellite Communications Terminal and AN/USC-28(V) Spread Spectrum Modem (U), TRW Defense and Space Systems Group, Redondo Beach, CA, HDL-CR-78-161-4 (May 1979). (SECRET)*

[3] *James D. Penar, Jere D. Dando, Ronald J. Chase, and Richard Underwood, High-Altitude Electromagnetic Pulse Design Practices: Application to AN/FSC-78 Satellite Communications Terminal, Landstuhl, Germany, Harry Diamond Laboratories HDL-SR-79-2 (May 1979).*

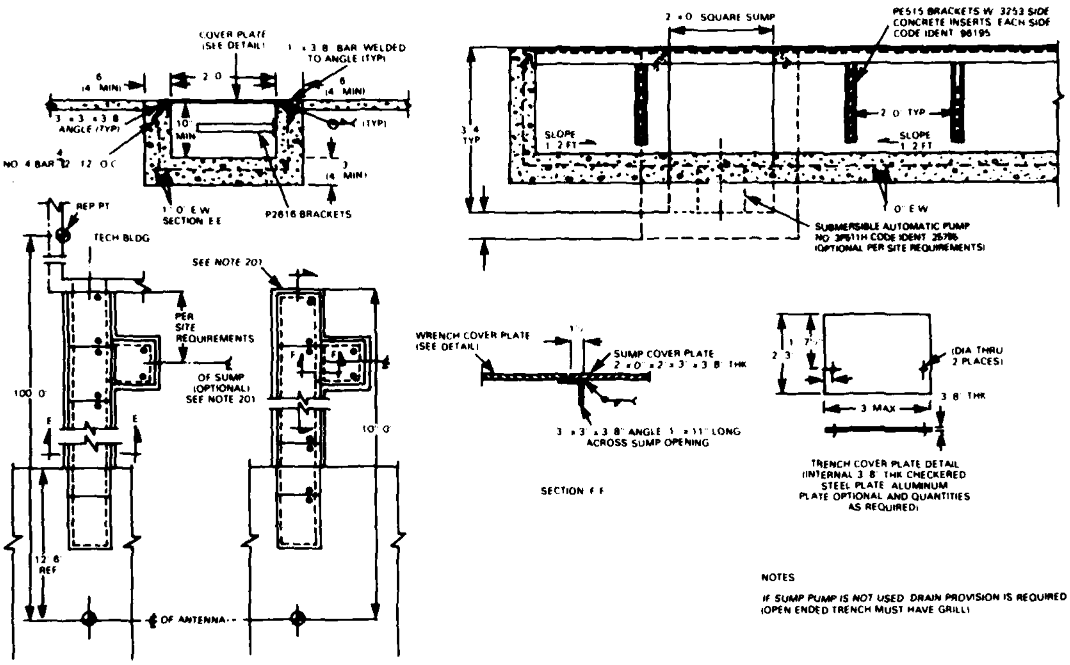


Figure 2. Drawing of site plan cable trench and sump (from U.S. Army Communication Electronics Engineering Installation Agency USACEEIA-CED STD-SS-0001, sheet 2).

2.2 *Antenna Foundation*

The foundation must be constructed with the rebar cadweld bonded to the anchor bolts to which the pedestal is bolted (fig. 3). The foundation rebar must be electrically connected at all intersections. Details of these hardening criteria must be included in any drawing established for the site (fig. 4).

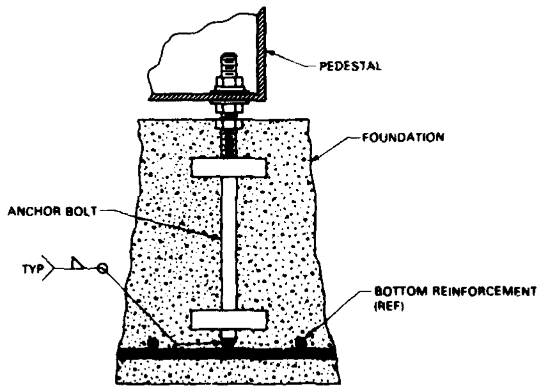


Figure 3. Detail of rebar cadweld bonded to antenna pedestal anchor bolt.

3. DESIGN CRITERIA—FACILITY HOUSING

3.1 *Shielding*

The facility housing will be constructed to provide a minimum of 30-dB electric field shielding effectiveness to plane electromagnetic waves. The shielding effec-

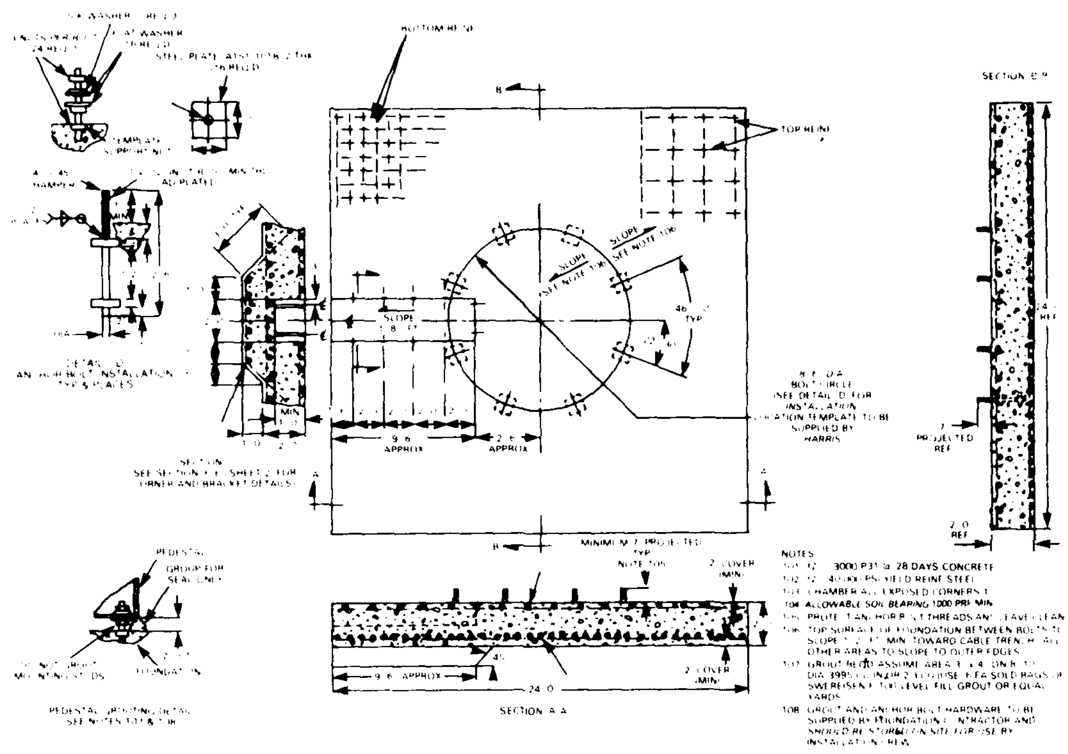


Figure 4. Drawing of antenna foundation (from U.S. Army Communication Electronics Engineering Installation Agency USACEEI-CED STD-SS-0001, sheet 1).

tiveness of the facility will depend on the amount and the distribution of electrically interconnected conductors in its construction. The necessity of apertures for communications, environmental control, and personnel access make it impractical to construct the facility as a continuous thick conductor—that is, a Faraday cage. Consequently, the facility must be shielded by constructing the building in a manner that approximates a metal enclosure.

The building could be constructed in one of three ways: (1) Install a pre-engineered (butler) type of building and tie the metal side panels to the foundation rebar along the perimeter either continuously or at a minimum of 1-ft (0.3-m) intervals. (2) Construct a building shielded with metal panels (18 gauge steel or 16 gauge aluminum), and extend these panels 3 ft (0.9 m) in the ground along the building perimeter (fig. 5). (3) Construct a poured-in-place concrete facility with all the rebar intersections tied together.

The roofs of these buildings should be electrically connected to the side panels of a pre-engineered or metal-paneled building (fig. 6 to 9). Electrical connectivity of the roof for the rebar facility must be made by cadweld bonding the roof panels to the wall rebar.

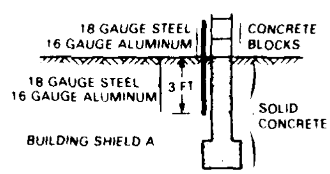


Figure 5. Overall building shield treatment.

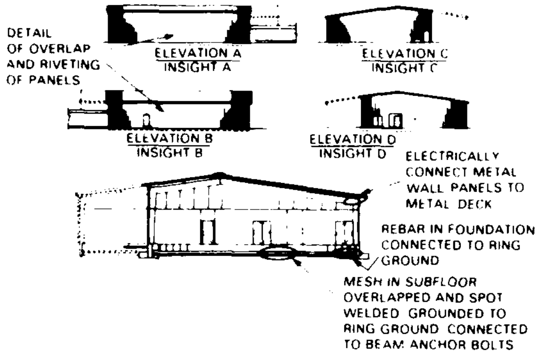


Figure 6. Operations building—elevations and sections showing HDL recommended modifications for electrical connectivity.

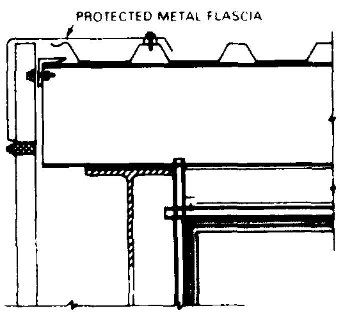


Figure 7. Detail showing metal siding panel bolted to roof panel and roof beam (typical).

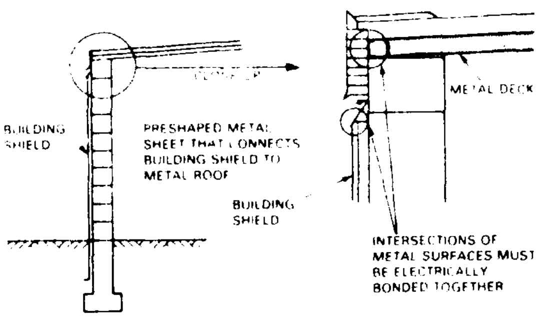


Figure 8. Possible means of intersection between building shield and metal roof.

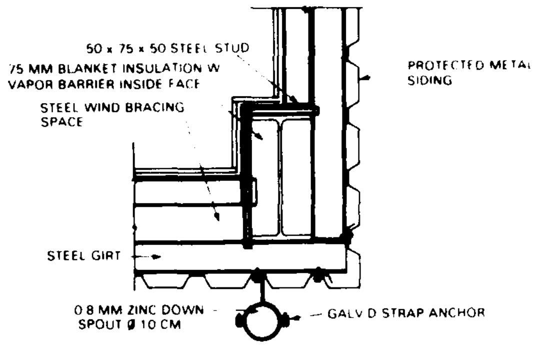


Figure 9. Detail showing metal panel exterior fastened with sheet metal screws—building corner interconnection (typical).

For paneled buildings, attention must be paid to the details of panel-to-panel interconnect to insure electrical continuity.

Panels made from aluminum or galvanized cold rolled steel are recommended. Shielding effectiveness factors, cost, fabrication properties, and availability identify the above materials as superior to all others. The sheet (panel) size is not critical, but should be as large as other constraints will permit to minimize the number of seams. Thickness of the panels is not critical, however, some of the fastener requirements would change slightly for very thin panels. The fastener requirements were based on panel thickness of about 50 mils (1.27 mm). (This thickness corresponds to 18-gauge sheet steel and 16-gauge sheet aluminum.) In relatively thin sheet metal, fasteners can cause bowing of the stock between the fasteners. Bowing reduces the metal-to-metal contact between the mating surfaces and degrades performance of the shield. The effect can be minimized by spacing fasteners closer or selecting a thicker shielding plate.

Metallic fasteners must be used in the shield fabrication. Acceptable methods of joining the panels are bolting, riveting, and tack welding. All of these methods require attention to fastener spacing and seam overlap.

Bolting may be done with bolt diameters equal to or greater than 3/8 in. (1.1 cm). To meet the minimum requirements for this shield with a minimum margin of safety, bolt spacings of 5 in. (12.7 cm) and panel overlap of 3 in. (7.6 cm) are sufficient for panel fastening. One can considerably improve the safety margin by reducing the bolt spacing (highest leverage factor) and extending the overlap. The maximum realistic shield integrity is reached with bolt spacings of approximately 3 in. and overlaps of 4 in. (10.16 cm). Bolts may be used with metal or rubber washers between the bolt-nut combination and the panels, but they are not required. A torque of approximately 18 to 25 ft-lb for 3/8-in. bolts and 22 to 29 ft-lb for 1/2-in. (1.27-cm) bolts is necessary to achieve the desired shielding integrity. Much larger values of torque have been found to slightly degrade the overall design, but the numerical values above are basically for guidance and are not critical.

Riveting also is an acceptable method for joining the panels. With it, a maximum spacing of 4 in. and an overlap of 3 in. are sufficient. As with bolting, the safety margin can be extended by reducing the rivet spacing (highest leverage factor) and extending the panel overlap. The maximum realistic shield integrity is achieved with rivet spacings of approximately 1 in. (2.54 cm) and overlap of 4 in.

Tack welding is an acceptable alternative to bolting or riveting. Welds are alternated on both sides of a 3-in. overlap joint; the weld seams are at least 1 in. long and spaced 5 in. apart. As with bolting and riveting, the safety margin can be extended by reducing the spacing of the welds and extending the lengths of the welded seams. It has been found that 30 percent alternating seam welds produce a joint equivalent in quality to a very good bolted joint.

Regardless of the method selected to join the panels, the finished joint must be treated to prevent corrosion. A waterproof seal is recommended over the outer surface of the joint and the fasteners. As an example of a practical implementation (fig. 10), channels would be attached to the building exterior, and a strip of sufficient width to meet the panel overlap criteria would be attached to the channel. The panels would then be fastened to the strip by one of the joining methods. There are many techniques for attaching threaded studs or nuts directly to the strip when panels are bolted, and special rivets speed fabrication in areas where access to both sides of the paneling is impossible.

Most important in fabricating an electromagnetic shield from component pieces is the contact surface forming the union of the pieces. To achieve an effective and reliable bond, the mating surfaces must be free of any foreign materials such as dirt, filings, or preservatives and nonconducting films such as paint, anodizing, oxides, or other metallic film. Mechanical and chemical means can remove the different substances from the bond surfaces. After cleaning, the bond should be assembled or joined as soon as possible to minimize recontamination of the surface. After the pieces are joined, the bond region should be sealed with protective agents to prevent bond deterioration through corrosion of the mating surfaces. This aspect of fabrication, the construction environment, will most probably determine the effectiveness of the completed shield.

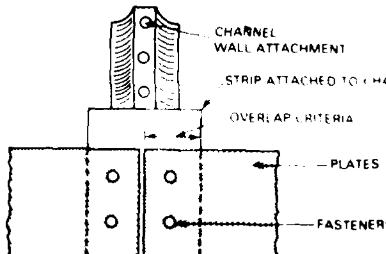


Figure 10. Sample configuration for panel shield attachment to building wall.

3.2 *Preparation of Shielding Material*

3.2.1 *Solid Materials*

Solid materials such as dust, dirt, filings, lint, sawdust, and packing impede metallic contact as mechanical stops between the surfaces. They can reduce the reliability of the connection by fostering corrosion. Dust, dirt, and lint absorb moisture and retain it on the surface. They may even promote the growth of molds, fungi, and bacteriological organisms, which give off corrosive products. Filings of foreign metals can establish tiny electrolytic cells that will greatly accelerate the deterioration of the surfaces.

The bond surface should be cleaned of all such solid materials. Mechanical means such as brushing or wiping are generally sufficient. Care should be exercised to remove all materials in grooves or crevices. If a source of compressed air is available, air blasting is effective for removing solid particles if they are dry enough to be dislodged.

3.2.2 *Organic Compounds*

Paints, varnishes, lacquers, and other protective compounds and oils, greases, and other lubricants are nonconductive and should be removed. Commercial paint removers can be effective. Lacquer thinner works well with oil-based paints, varnishes, and lacquer. If chemical solvents do not remove the organic compounds, scrapers, wire brushes, power sanders, sandpaper, or sand blasters might remove them mechanically. With mechanical techniques, care should be exercised to avoid removing excess material from the surfaces. Final cleaning should be done with a fine grit sandpaper (such as 400 grit) or steel wool. After all of the organic material is removed, abrasive grit or steel wool filaments should be brushed or blown away. Finally, the surface should be wiped with denatured alcohol, dry cleaning fluid, or lacquer thinner to remove any remaining oil or moisture films.

As a word of caution, many paint solvents, such as lacquer thinner and acetone, are highly flammable and toxic. They should never be used around open flames. Ventilation must be adequate and the fumes must not be inhaled. Oils, greases, and other petroleum compounds should be wiped with a cloth or scraped off. Residual films should be dissolved with an appropriate solvent. Hot soapy water can remove any remaining oil or grease. If water is used, the surface must be thoroughly dried before the bond is completed.

3.2.3 *Platings and Inorganic Finishes*

Many metals are plated or coated with other metals or are treated to produce surface films to improve wearability or resist corrosion. Metal platings such as gold, silver, nickel, cadmium, tin, and rhodium should have all foreign materials removed by brushing or scraping and all organic materials removed by an appropriate solvent. Since such platings are usually very thin, acids and other strong etchants should not be used. Once the foreign substances are removed, the bond surfaces should be burnished to a bright shine with fine steel wool or fine grit sandpaper. Care must be exercised not to remove excessive metal. Finally, the surfaces should be wiped with a cloth dampened in denatured alcohol or dry cleaning solvent and allowed to dry before the bond is completed.

Chromate coatings such as iridite 14, iridite 18P, oakite 36, and alodine 1000 offer low resistance and resist corrosion. These coatings do not need to be removed. Any chromate coatings meeting the MIL-C-5541 requirements[4] should be left in place.

Many aluminum products are anodized for appearance and corrosion resistance. Since these anodic films are excellent insulators, they must be removed before bonding. Either aluminum parts to be electrically

[4] *Chemical Conversion Coatings on Aluminum and Aluminum Alloys, MIL-C-5541 (30 November 1972)*

bonded should not be anodized or the anodic coating must be removed from the bond area.

3.2.4 Corrosion Products

Oxides, sulfides, sulfates, and other corrosion by-products must be removed because they restrict or prevent metallic contact. Soft products such as iron oxide and copper sulfate can be removed with a stiff wire brush, steel wool or other abrasives. Removal down to a bright metal finish is generally adequate. When pitting has occurred, the surface may have to be refinished by grinding or milling to smooth and even the contact surface. Some sulfides are difficult to remove mechanically and may need chemical cleaning and polishing. Oxides of aluminum look clean, and thus the appearance of the surface cannot be relied upon as an indication of the need for cleaning. Although the oxides are hard, they are brittle and roughening of the surface with a file or coarse abrasive prepares aluminum surfaces for bonding.

3.2.5 Completion of Bond

After the mating surfaces are cleaned, the bond members should be assembled or attached within 30 min if at all possible. If more than 2 hr is required between cleaning and assembly, a temporary protective coating must be applied. This coating must be removed before the bond is completed.

The bond surfaces must be kept free of moisture before assembly, and the completed bond must be sealed against the entrance of moisture into the mating region. Acceptable sealants are paint, silicone (noncorrosive) rubber, grease, and polysulfates. Where paint has been removed before bonding, the completed bond should be repainted to match the original finish. Paint should not be thinned too much. Excessively thinned paint may seep under the edges of the bonded components and impair the quality of the connection.

3.3 Grounding

The facility grounding scheme should be designed to meet normal requirements of safety and lightning protection. The building shield may require additional HEMP protection. If no connectivity between metallic exterior walls and the subfloor grid exists, the exterior walls must extend into the earth (sect. 3.1 and fig. 11). Also, ground rods must be spaced 3.3 ft (1 m) apart and bonded with as short a lead length as possible to the walls. This grounding is not required if the exterior metal walls are made electrically continuous to the subfloor mesh (sect. 3.1).

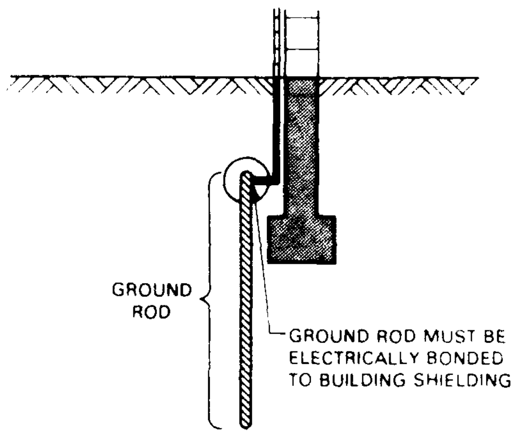


Figure 11 Position of ground rod for building shield.

4. DESIGN CRITERIA—TECHNICAL EQUIPMENT ROOMS

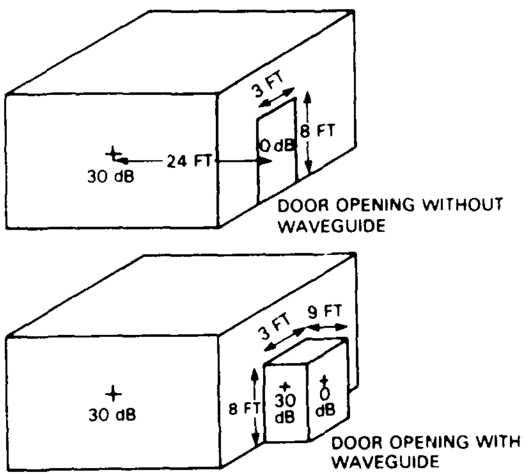
4.1 Architectural Criteria

4.1.1 Floors

The subfloor area beneath the raised floor must have the rebar mesh sections bonded together and to the wall shield (exterior metal panels or rebar in poured-in-place facilities). All connections should be cadwelded

4.1.2 Doors

Two options may be used to prevent compromise of the building shield by the use of doors: a shielded vestibule of appropriate dimensions or radio frequency (rf) types of doors. A vestibule (fig. 12) constructed as part of the metallic building exterior provides a waveguide below cutoff for frequencies of concern and allows use of any type of door.[5] For a 3-ft-wide vestibule, a 30-dB shielding requirement, height h, and depth ℓ, the dimensions should conform to 30 dB = 27.3 (ℓ/h). Figure 12 shows that a depth of 9 ft (2.7 m) is required for a height of 8 ft (2.4 m). Standard rf doors should be made electrically continuous through the door frames to the shield.



NOTE DOOR SIZE IS SUGGESTED OPTIMUM DIMENSIONS FOR INSTALLING SUGGESTED HARDENING DESIGN CRITERIA

Figure 12. Shielding effectiveness of installing metal vestibule at exterior doors.

A less expensive but less desirable option is the retrofit of standard metal doors with rf finger stock and braid straps to the shield as shown in figure 13. Following a maintenance schedule will assure continued integrity of the finger stock. Further, all but one or two of the doors should be permanently locked (but equipped with emergency quick unlock crash bars) to reduce the chances of compromising the rf integrity through the doors.

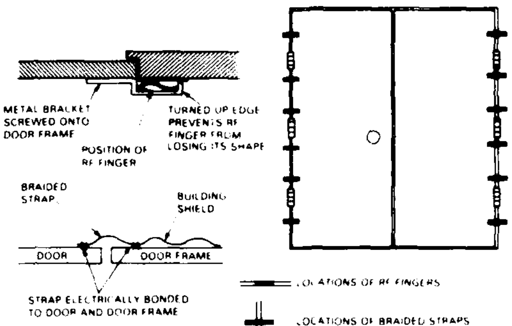


Figure 13. Electromagnetic pulse shielding of metal door by retrofit method

4.2 Structural Criteria

4.2.1 General

In addition to requirements in the AN/GSC-39 facility design criteria, the technical equipment rooms should be part of a structure that incorporates the electromagnetic pulse (EMP) hardening features of section 4.2.2. A design goal to route penetrating metallic conductors is to have one general area of entry into the facility.

4.2.2 Special Requirement—Heat Exchanger

The heat exchanger (transmitter) conduit to the facility should be metallic and circumferentially bonded to the facility shield or building rebar (in poured-in-place structures).

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[5] *Morris Campi, Survey and Review of Aperture Shielding for EMP/RFI Fields, Harry Diamond Laboratories HDL-TM-78-25 (December 1978).*

4.3 *Mechanical Criteria*

4.3.1 *Plumbing*

All plumbing may be specified to be of electrically conducting or nonconducting material. If conducting material is used, it should be circumferentially bonded to a metal entry plate at the building entrance as shown in figure 14. This entry plate should be bonded to the shield of a shielded or pre-engineered building.

Futhermore, all piping should be placed below grade. If the plumbing is nonconducting, the building entry need not be treated.

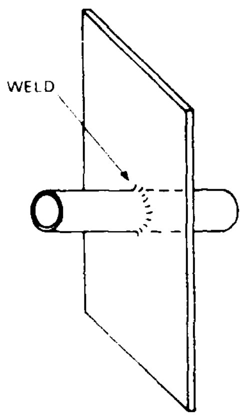

Figure 14. Entry plate treatment of conductive plumbing at facility and terminal interfaces.

The filtration system used to filter 5-micron (5-μm) or larger particles must be augmented with a 1/4-in. (3-mm) hexagon by 1-in.-thick honeycomb rf-electromagnetic interference (EMI) filter matrix as depicted in figure 15. This filter matrix must be positioned so that it does not impede the normal operation of the primary filtration system. If the filtration system is mounted to the side of the facility, the honeycomb matrix should be conductively bonded to a baseplate or frame that is attached to the building shield by welding, bolts, or rivets (sect. 3.1.1). If the building is a poured-in-place structure, the honeycomb should be attached to the building rebar by framing channels. For roof-mounted vents, minimal bonding is needed.

If external heat condensers are used, all power, control, and cooling lines must be bonded to the building shield by an entry plate or bonded to the foundation rebar as shown in figures 16 and 17 (p. 14).

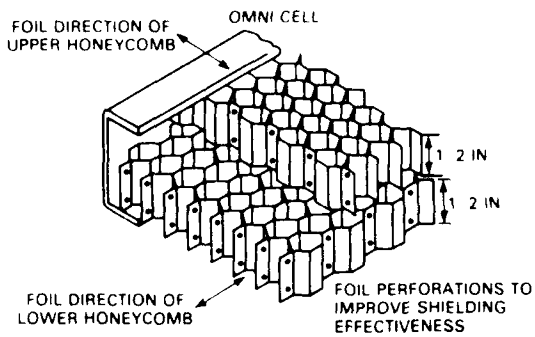

Figure 15. Section of Metex ventilating panel shielded against electromagnetic interference.

4.4 *Electrical Criteria*

4.4.1 *Facility Power*

Prime power feeders to the building are to be run in a rigid metal conduit that is circumferentially bonded to the building shield or foundation rebar at the point of entry. A shielded power entry vault should be used just outside (fig. 18) or inside the building for placement of surge arrestors (such as Joslyn 1250-05's) installed across each phase wire of the transformer secondary coil (fig. 19). These surge arrestors should be followed by a suitable power line filter such as an ELM 1866 (manufactured by Lectromagnetic) as illustrated in figure 19. Lead lengths to ground for the filters and the arrestors should be minimized, and the entry vault should be totally shielded.

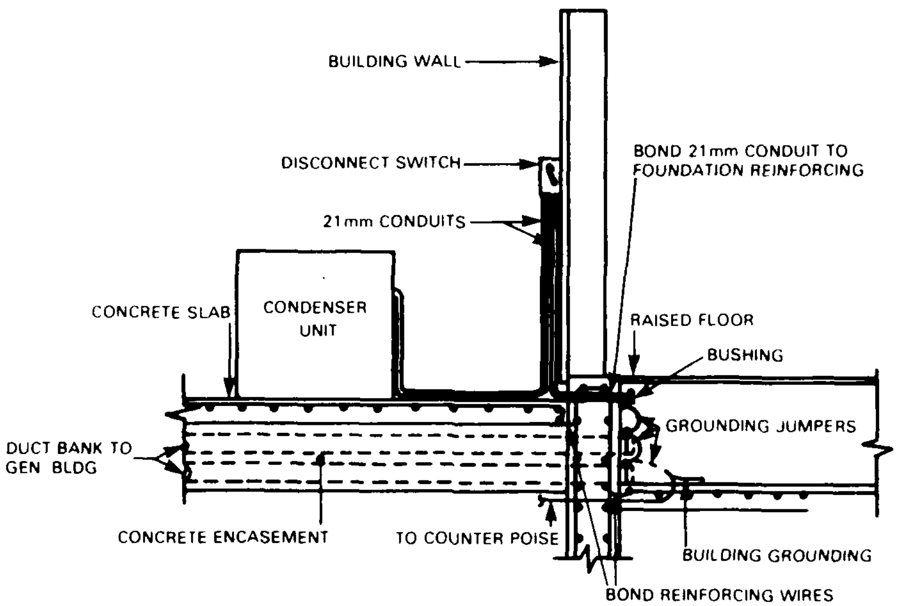

Figure 16. Detail showing penetration treatment of condenser unit conduit and prime power conduits at building entry.

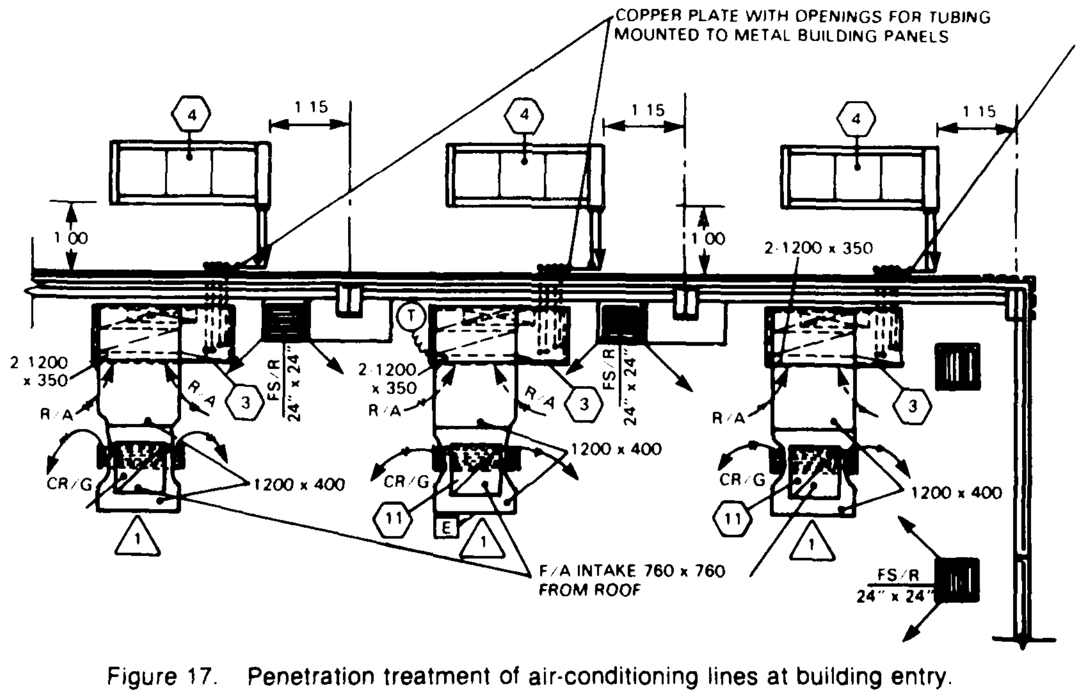

Figure 17. Penetration treatment of air-conditioning lines at building entry.

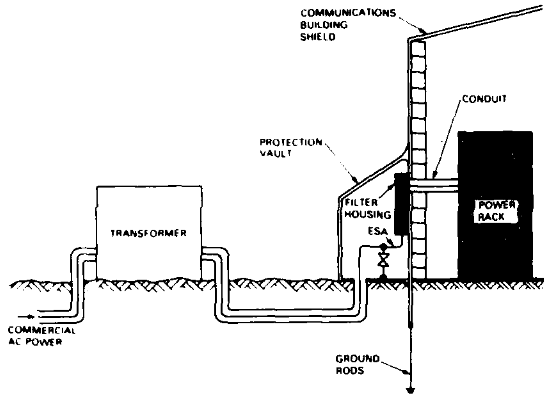

Figure 18. Hardened commercial power penetration using surge arrestors (ESA's) and filters.

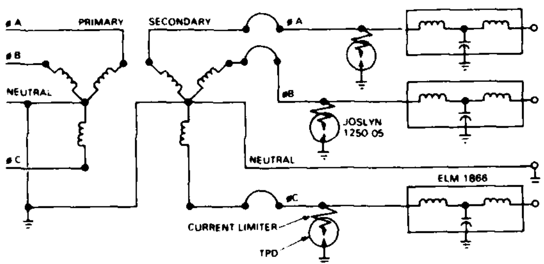

Figure 19. Detail of power line penetration pretection using surge arrestors and filters.

4.4.2 *Communications Lines*

The HEMP protective criteria are separately provided for interconnect communications facilities. These communications lines are of varying length and enter the facility in several ways depending upon the site. Some common configurations are (1) *underground* runs of direct burial, unshielded conduit, or duct bank with single- and double-shielded cables, (2) underground rigid metallic conduit containing unshielded and single-shielded cables, and (3) shielded duct banks or trenches with single- and double-shielded cables.

In configuration (1), the component wires must be treated with terminal protection devices (TPD's) such as Zener diodes and metal oxide varistors installed within a cable vault just outside or inside the building (fig. 20). The cable vault may be below grade and must be shielded, but accessible for maintenance. A shield divider between the inputs and the outputs of the TPD's must be well grounded. The selection of TPD's is based upon the operation of equipment and other aspects discussed in the ICF design criteria.

In configurations (2) and (3), the trench or duct-bank shield (rebar or mesh) or conduit must be bonded to the shield of the building or foundation rebar. A cable vault may not be required.

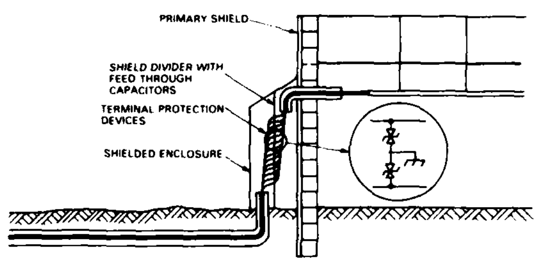

Figure 20. Hardened communication cable penetration.

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